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MOTION ANALYSIS OF SWATH VESSEL USING STRIP THEORY BASED PROGRAM (SEDOS) WITH EXPERIMENTAL VALIDATION

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ABSTRACT

The paper presents a study on motion analysis of SWATH vessel through a strip theory-based program (SEDOS) with experimental validation in waves. The concept of the SWATH has been developed over the last few decades, and today they are being constructed for a variety of different missions, relating to naval surveillance, oceanographic research and transportation of passengers or crew to floating installations such as offshore wind-farms. SWATH vessels are inherently more prone to larger pitching motions as compared with mono-hulls due to the characteristic slender water-plane area design feature. This paper presents the comparison of damping and restoring coefficient of SWATH and monohull of equivalent displacement. Also, pitch and heave motion responses of SWATH vessel using strip theory-based algorithm (SEDOS) with experimental validation are discussed. The results obtained from the analysis shows damping and restoring coefficient in pitch and heave for SWATH vessel are comparably less than equivalent displacement monohull. Pitch and hurl responses of SWATH without any appendages obtained from SEDOS and a result shows a reasonable agreement with experiments. However, the pitch response obtained in the analytical solution (SEDOS) seems to be over-predicting the response at resonance. The heave response at peak gives the reasonable match. However, there is a degree of scattering of the experimentally obtained values as compared to the analytical prediction.

KEYWORDS: SWATH, SEDOS & Monohull

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INTRODUCTION

Small Water-plane Area Twin Hull (SWATH) ship originated as an inspiration from the form of semi-submersibles with their characteristic submerged pontoon hulls and prismatic support legs with relatively small waterplane area. SWATHs have been in existence for more than the last three decades. It consists of a pair of lower hulls, which are connected to the upper platform by single or twin strut. It has small water-plane at a designed draft, which results in more extended natural periods and reduced buoyancy force changes.

As a result SWATH ships have a remarkably stable platform configuration which is highly attractive for science and engineering operations at sea. They can be engineered to have outstanding seakeeping ability; they have high deck area to displacement ratio, and can many meet many operational requirements as constant displacement vessels. Typical applications are as passenger ferries, cruise ships, oceanographic research and diving support vessels and patrol vessels. Due to their superior ride quality, acceptable acceleration levels for human habitability and therefore comfort, SWATH ships are being built in different variations and increasing sizes. SWATH ships by their nature have small Waterplane area, typically less than 50% of that compared with a

monohull of equal displacement. Waterplane area is not drastically reduced since a reasonable waterplane area is required to prevent too low a frequency of oscillation. On the other hand increased water-plane area increases stiffness. This leads to increased incidence of swing resulting in a shorter heave period. Salvesen (1973) presented an overview of the seakeeping characteristics of SWATH ships. Experiments performed on a 67m (220-ft) SWATH ship showed that in very high head seas mainly in long swells, without foils, the vessel experiences some significant motions. Also in quartering and following seas, a SWATH ship undergoes pitching if not equipped with foils or control surfaces. Gersten (1974) conducted experiments for stability, seakeeping and resistance characterisation on a naval SWATH ship. Comparisons showed that in random waves the vessel had less severe motions than a conventional mono-hull. Useful horsepower for the SWATH was also found to be appreciably higher than that for a traditional mono-hull. Yoshida *et al.* (2011) presented the conceptual design of a ship necessitating no speed reduction and absolutely no slamming in the waves in sea state 7. The new concept design had a smaller water plane compared to the conventional SWATH ship to avoid any resonance peak. Motion responses were significantly reduced compared with those of mono-hull, trimaran or ordinary SWATH. Rahimuddin *et al.* (2012) reported the reaction of semi SWATH in the following sea with fin stabiliser. Active fins stabiliser provided a significant reduction effect of the bow-diving. The meaningful non-linear change response emerged at L_w/L_s= 1.5 with both fins stabiliser was fixed. The bow diving occurred at high wave steepness H_w/L_w= 0.08 with fixed fin stabiliser. The extreme bow diving occurred at L_w/L_s= 1.25. Based on the significant work described in the preceding section, the objectives of the present work are to obtain the effect of water-plane area on damping and restoring coefficient in pitch and heave of SWATH vessel in regular waves. Also to perform the numerical analysis to calculate responses of SWATH in a steady stream for stable condition and validate the results by conducting experiments on a SWATH vessel at laboratory scale to obtain motion response in waves.

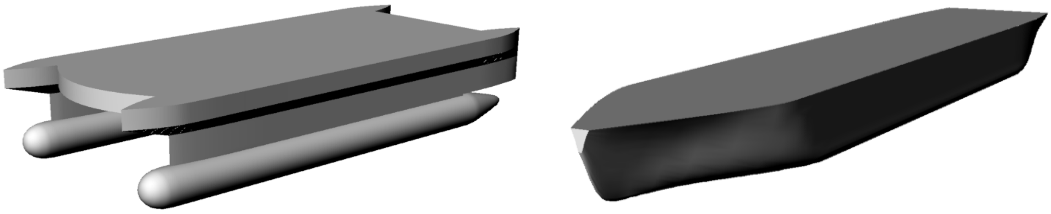
RELATED WORKS

The hydrodynamic qualities of three unique submerged body types of the SWATH sort are contemplated in light of their controlling and movement execution. A SWATH is a twin-body dispatch plan that holds different favourable circumstances over the ordinary mono-frames. The state of the submerged structure and the struts decide the protection and movement attributes of the SWATH. It is imperative to touch base at an ideal body shape for most great execution. SHIPFLOW, a CFD apparatus created mainly for the marine business, is utilised to gauge and analyse the protection and fuelling attributes of the three plans. SEDOS, a movement investigation bundle in light of strip hypothesis, is employed to evaluate the seakeeping attributes of the frames. The remark is made on the precise execution of trials when looked at against the tank test comes about, together with the comes about because of different numerical forecast techniques.

In this examination, the reaction of a Semi-SWATH (Small Waterplane Area) transport in following ocean condition with blades stabiliser was examined. In the waves, a ship moves with occasional dynamic surge movement caused by the external ocean wave power and minute. Moreover, in following oceans with high soak waves, the vessel can surf, high pitch, bow-dive, and lead the ship in the non-linear reaction. A digital reproduction program in 3DOF (surge, hurl and pitch) with time differing model condition was created to examine the ship reactions. This investigation concentrates on the impact of a variety of wave parameter to the ship reaction and the implications of balances stabiliser; settled and dynamic. The numerical re-enactments were approved with demonstrating tests in towing tank. Re-enactments come about shown that the following ship reaction was balanced out adequately and decreased pitch point by vigorous blades stabiliser activity.

GEOMETRY AND TEST CONDITION

The analysis was carried out on the SWATH 10 vessel [Lewandowski] and General cargo vessel to calculate damping and restoring coefficient to demonstrate the effect of waterplane when both vessels had the same displacement. The geometrical parameters of both the ship mentioned. Initially, an analysis was performed in SEDOS to find the effect of waterplane area on damping and restoring coefficient of SWATH and general cargo vessel. The further SEDOS study was carried out to calculate response amplitude operator (RAO) in pitch and heave for SWATH vessel. Results were validated with experiments performed at IIT Madras.



SWATH **Cargo vessel**

Figure 1: Solid Model of SWATH and Cargo Vessel

Table 1: Geometrical Parameters of SWATH and General Cargo Vessel

Particulars	SWATH (1:21.77)	Cargo Vessel (1:31.13)
Displacement (Kg)	57	57
Water line length (LWL) (m)	1.75	2.1715
Depth (m)	0.370	0.135
Draft (m)	0.209	0.08
Maximum beam (m)	0.75	0.385

NUMERICAL ANALYSIS

The SWATH vessel has some disadvantages like reduced damping and restoring forces in pitch and heave see. The calculations have been performed on the two hull forms namely a SWATH and a mono-hull of equivalent displacements. The hydrodynamic coefficients representative of forces acting on the ship hull and the motion characteristics are obtained using SEDOS. The method is based on strip theory. The program performs a calculation for the motion analysis of ship in regular waves and natural, stationary seas. The background and methodology for using SEDOS are briefly outlined here (Soeding, 1988).

SEDOS uses strip theory to calculate ship motions. The method uses a formulation of equations of motion limited to rigid-body subjected to overwhelming harmonic forces and moments due to free-surface waves with small wave slopes. The technique is developed under the assumption of infinite water depth. The ship is assumed to maintain a constant mean forward speed and a straight mean course. The submerged portion of the hull is considered to be slender enough for the rate of lengthwise variation of hydrodynamic pressures to be small. The method takes into account external forces and moments acting on the ship. These comprise effects of gravity, buoyancy, stress due to water particle motions (Froude-Krylov forces), and radiation of waves due to the ship's actions, scattering (i.e., diffraction) of incident waves.

The analysis has been carried out for a US Coastguard vessel model, and the ship is designated as SWATH 10 (Lewandowski, 1994). The graphs show that the damping and restoring forces are much smaller for the SWATH than for the same displacement mono-hull. Hence SWATH is more prone to pitch and heave response. These motions in the sea are

also responsible for a loss of ship speed as well as for the occurrence of slamming, large accelerations and other dynamic effects. Wherever possible, it is necessary to reduce such motions of a ship for comfortable and safe operation. Thus the deleterious effects of such movements are dynamic loads on the ship hull as well as discomfort for crew or passengers and involuntary reduction of speed. Hence the introduction of passive and active control devices can help control the amplitude, rate and acceleration of the motion as well as some of the associated dynamic effects. Any pay-offs due to the introduction of such devices must also be analysed. Possible consequences are increased resistance leading to extra power requirement, any possible induced wave interaction effects between the two hulls etc.

Table 2: Comparison of Stiffness in Heave and Pitch of SWATH and Cargo Vessel

Particulars	SWATH (1.21.77)	Cargo Vessel (1:31.13)
Pitch (t-m)	0.125	2.47
Heave (t/m)	1.05	7.61

EXPERIMENTAL ANALYSIS

The numerical simulation was performed for SWATH vessel to calculate pitch and heave responses in waves in the stationary condition. The results are validated by performing physical motion tests and compare the motions in waves. The hull model was made on 1:21.77 scale in fibre-glass and prepared for mass-based properties viz., a centre of gravity location and radii of gyration. The geometry-based data are given. All related mass characteristics were simulated in the model. The centre of gravity is at 3.4% of the hull length forward of midship and at height 0.48 D, where D is the depth of the ship.

The roll radius of gyration K_{xx} = is 39% of the maximum hull beam

The pitch radius of gyration K_{yy} = is 29% of the full length.

Table 3: Geometrical Parameter of SWATH 10

Specification	Prototype	Model(1:21.77)
Displacement	594.4t	57kg
Strut length (m)	41.76	1.92
Overall length(m)	38.16	1.75
Hull length (m)	37.92	1.74
Maximum beam (m)	18	0.83
Depth (m)	7.92	0.36
Draft (m)	4.416	0.206
Strut + hull wetted area (m^2)	864	1.82
VGC above the baseline (% of depth)	73%	73%
LCG % of hull length forward of midship	3.4%	3.4%
GM_L(% of full length)	19.7%	19.7%
Roll radius of gyration k_{xx} (% of maximum beam)	39%	39%
Pitch radius of gyration k_{ey} (% of full length)	29%	29%
C_B	0.216	0.216

MOTION STUDIES IN REGULAR WAVE CONDITIONS

The sea-keeping tests were conducted in the wave flume measuring 90.0 m x 4.0 m x 2.5m water depth at IIT Madras. The Motion Reference Unit (MRU) was used to determine the responses of a vessel regarding heave, roll, and pitch and heading angle and it was installed at the centre of gravity point of the boat. For measurement of wave elevation time series, standard conductivity type wave probes were used. The probe was kept at a distance of 20m from the

wavemaker flap. The distance between model and wave probe is the nominal distance so that diffraction and reflection effects are avoided in the measurements of waves.

The tests were conducted for the permanent condition in the head sea for the SWATH vessel to calculate RAO in pitch and heave. Fig. 4.1 shows the physical simulations in the wave flume. The photographs also show the underwater body of the SWATH. Fig. 4.1 shows the instantaneous maximum pitch response frame at resonance condition where on the model scale the wave period is 2.4s and wave height corresponding to 1/50 slope wave.

Figure 2: Instantaneous Resonance Maximum Pitch Response

Pitch and heave responses of SWATH without any appendages obtained from SEDOS as shown in Figure.4.2. Results show a reasonable agreement with experiments. However, the pitch response received in the analytical solution seems to be over-predicting the response at resonance. The heave response at peak gives the reasonable match. However, there is a degree of scattering of the experimentally obtained values as compared to the analytical prediction.

CONCLUSIONS

The paper develops and presents an efficient methodology for the numerical analysis of a SWATH by using SEDOS. An independent motion analysis study using SEDOS (twin hull motion analysis software, Soeding 1988) has also been undertaken and compared with the results from physical experiments conducted in stable conditions in head sea waves. Results show a reasonable agreement with experiments. However, the pitch response obtained in the analytical solution seems to be over-predicting the response at resonance. The heave response at peak gives the reasonable match. However, there is a degree of scattering of the experimentally obtained values as compared to the analytical prediction. Also, Analysis shows an effect of water-plane area on damping and restoring forces, for two different ship models (SWATH and General Cargo vessel) of the same displacement. The results obtained from SEDOS shows good agreement with experiments. SEDOS is efficient, economical and less time-consuming tool to acquired responses of a vessel.

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